

EVALUATION OF ENVIRONMENTAL EFFECTS ON GPS NAVIGATION SYSTEMS: SCINTILLATION DATA COLLECTION

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14. ABSTRACT Irregularities in the ionospheric electron density may cause amplitude and phase scintillations in GPS signals. To mitigate the effects of scintillation, the environment should be monitored. This report details the receiver features needed to provide the information and suggests a number of commercial receivers which meet the requirements.					
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Background

It is well known that irregularities in the ionospheric electron density occur naturally, particularly in equatorial and polar regions. These irregularities appear as electron density structures, and may cause propagation disturbances in transionospheric radio frequency signals. Among the disturbances produced by these environments are random variations in the amplitude and phase of a propagating wave. These random variations, or scintillations, may stress the ability of a satellite link receiver to accurately process the received signal.

The navigation signals of the Global Positioning System (GPS) are among those that are affected by naturally-occurring ionospheric irregularities. Scintillation of these L-band signals can disrupt GPS receiver performance, affecting pseudonoise (PN) code and carrier tracking, data demodulation, and navigation solution. Because of the growing application of GPS-based navigation, it is important to understand L-band ionospheric disturbances and their effects on GPS receiver performance.

GPS receivers are useful for observing ionospheric disturbances because the configuration of the satellite constellation allows simultaneous observation of numerous propagation paths at a common frequency from any location on earth. Furthermore, the collection of L-band scintillation data can be correlated with receiver response and navigation performance. By recording key receiver output parameters simultaneously with received signal characteristics, designers can understand receiver performance sensitivities to real environments — a useful step in the development of robust GPS receivers. The recorded scintillation realizations can be used directly (or modeled parametrically) in highly-detailed computer simulations of GPS receivers to assess performance and develop receiver mitigation designs, and subsequently to support testing of robust GPS receivers.

The principal goal of this effort was to assemble a data-logging GPS receiver system that can be used to monitor ionospheric scintillation. Secondary efforts involved evaluations of data from other measurement efforts for use in GPS scintillation investigations.

Data-logging GPS receiver system

There are several key receiver features required to provide the necessary performance for data-logging of propagation disturbances. First, the key data-logging outputs are the received signal amplitude and phase. Data-logging rates of 20 Hz to 50 Hz are required to provide the necessary temporal resolution of the fast signal scintillation that may occur at L-band. These data output rates may stress the hardware and software of many commercial receivers that typically are designed to provide more routine data outputs at rates of a few Hz or less. Custom-built receivers could be tailored to provide the special outputs needed at high data rates; however, the costs are significant.

Simultaneous data-logging for all satellites in view is desired to enable characterization of as much of the sky as possible, and to maximize the likelihood of capturing data for localized ionospheric disturbance events. Since 12 or more satellites may be observed from most locations at various times each day, a corresponding number of independent receiver

channels is desired. Dual frequency tracking of L1 and L2 GPS downlinks is desired to facilitate measurement of total electron content (TEC) levels.

The recorded signal outputs must be unaffected by receiver automatic gain control (AGC) circuitry. Therefore, if the receiver has variable gain, the gain variation should be slow compared to the signal variation rates. This requires an AGC time constant of tens of seconds or longer.

Low phase noise oscillators are needed to minimize receiver phase noise in the signal measurements. A provision to accept an optional external low-noise oscillator input is a desirable feature.

A small number of commercially-available GPS receivers approach the desired system characteristics. One of the options is a single-frequency system that includes custom modifications to record scintillation parameters. This system, from GPS Silicon Valley, includes a commercial GPS board that interfaces with a personal computer (PC). A modified dual-frequency version of this system could be developed using what is often referred to as a codeless tracking technique to extract the L2 signal without knowledge of the encrypted P-code that is used on L2. Since this type of receiver would not track the true L2 Y-code (encrypted P-code), L2 measurements would be subject to significant losses. This approach is not practical for observing scintillation on L2, since fades would be difficult to measure. In addition, the L1 output scintillation measurements from this system are processed quantities that summarize the signal statistics rather than the required raw signal data themselves.

Another option considered for the data-logging system is based on the TurboRogue[®] receiver from Allen Osborne Associates. This receiver can track up to 8 satellites, including L1 C/A code and codeless tracking of the L1/L2 Y-code. Although the codeless tracking measurements (including L2) would be unsuitable for scintillation data gathering, there is a crypto-enabled version that could provide conventional L2 Y-code tracking and suitable scintillation measurements. A special software function would provide output of amplitude and phase data for both L1 and L2 at a 50 Hz rate. Although up to 8 satellites may be tracked simultaneously, the 50-Hz data output is supported only for up to 2 or 3 satellites at a time. The receivers providing 50-Hz data are selectable dynamically, with other receivers providing low rate data output.

Another receiver alternative considered is the Ashtech ZY-12 model. This receiver tracks up to 12 GPS satellites simultaneously at both L1 and L2. The receiver comes either with or without a crypto module, with the non-crypto version using a form of codeless tracking to provide dual-frequency (lossy L2) measurements. The software used in the ZY-12 includes an option (which is largely undocumented) to output signal data at a 20 Hz rate. Although the data rate is lower than the Allen Osborne Associates receiver, the ability to provide high rate data for all satellites in view (up to 12) is considered an advantage.

The Ashtech ZY-12 receiver was selected for the data-logging system. Although the crypto capability is not fully implemented in the receiver acquired, it may be readily upgraded to include the crypto option. The receiver includes an input for an external frequency reference, in the event the receiver's internal oscillator introduces undesirable levels of phase noise. A choke ring antenna is provided to reduce ground-based multipath that may interfere with ionospheric scintillation measurements.